IS/IEC 60793-1-20 (2001): Optical fibres, Part 1: Measurement methods and test procedures , Section 20 Fibre geometry [LITD 11: Fibre Optics, Fibers, Cables, and Devices]

BLANK PAGE

भारतीय मानक

प्रकाशिक तंतु

भाग 1 मापन विधियाँ और परीक्षण प्रक्रियाएँ

अनुभाग 20 तंतु ज्यामिति

Indian Standard

OPTICAL FIBRES

PART 1 MEASUREMENT METHODS AND TEST PROCEDURES

Section 20 Fibre Geometry

ICS 33.180.10

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

July 2009

Price Group 9

Fibre Optics, Fibres, Cables and Devices Sectional Committee, LITD 11

NATIONAL FOREWORD

This Indian Standard (Part 1/Sec 20) which is identical with IEC 60793-1-20 : 2001 'Optical fibres — Part 1-20: Measurement methods and test procedures — Fibre geometry' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Fibre Optics, Fibres, Cables and Devices Sectional Committee and approval of the Electronics and Information Technology Division Council.

The text of the IEC Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker, while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

The technical committee responsible for the preparation of this standard has reviewed the provisions of the following International standard and has decided that it is acceptable for use in conjunction with this standard:

International Standard	*Title*
IEC 61745	End-face image analysis procedure for the calibration of optical fibre geometry test sets

Only the English language text in the International Standard has been retained while adopting it in this Indian Standard, and as such the page numbers are not the same as in the IEC Standard.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

OPTICAL FIBRES

PART 1 MEASUREMENT METHODS AND TEST PROCEDURES

Section 20 Fibre Geometry

1 Scope

This part of IEC 60793 establishes uniform requirements for measuring the geometrical characteristics of uncoated optical fibres.

The geometrical characteristics of uncoated optical fibres are fundamental values and are necessary for carrying out subsequent procedures such as handling, splicing, connectorization, cabling and measurements.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61745, *End-face image analysis procedure for the calibration of optical fibre geometry test sets*

3 Overview of method

This standard gives four methods for measuring fibre geometry characteristics which are given in terms of the following parameters:

- cladding diameter;
- cladding non-circularity;
- core diameter (category A fibre only);
- core non-circularity (category A fibre only);
- core-cladding concentricity error;
- theoretical numerical aperture (optional – category A fibre only).

1—265 BIS/ND/2009

Table 1 – Measurement methods

Method	Characteristics covered	Fibre category(ies) covered	Former designation
A Refracted near-field	All	All A and B [a, b]	IEC 60793-1-A1A
B Transverse interference	Core diameter, core non-circularity and theoretical numerical aperture	All A [b]	IEC 60793-1-A1B
C Near-field light	All but theoretical numerical aperture	A1, A2, A3, all B [c]	IEC 60793-1-A2
D Mechanical diameter	Cladding diameter and cladding non-circularity only	All [d]	IEC 60793-1-A4

[a] The core diameter of single-mode fibres is not specified.

[b] Measurement of core diameter and the maximum theoretical numerical aperture of category A1 fibres may also be made by this method.

[c] The single near-field scan method can be used to determine a cross-sectional diameter of the core of category A1 fibres. This cross-sectional diameter may deviate from the core diameter determined by method C due to effects of core non-circularity. A core non-circularity value can be determined by scanning in multiple axes.

[d] In practice, for smooth and substantially circular fibres, method D gives a similar result to that obtained by methods A, B and C, in which case non-circularity of fibre can also be determined.

Information common to all four methods appears in clauses 2 to 10, and information pertaining to each individual method appears in annexes A, B, C and D, respectively.

4 Definitions

For the purpose of this part of IEC 60793, the following definitions apply.

4.1

reference surface

surface defined in the detail specification, which may be either core or cladding

4.2

core concentricity error

distance between the centre of the cladding and

- the centre of the near field profile for category B fibres;
- the centre of the core, for category A fibres.

4.3

core diameter of category A multimode fibre

defined from the refractive index profile as that diameter passing through the core centre and intersecting the index profile at the points n_3 such that:

$$n_3 = n_2 + k(n_1 - n_2)$$

where

n_2 is the refractive index of the homogeneous cladding;

n_1 is the maximum refractive index;

k is a constant commonly called the "k factor".

The refractive index profile can be measured by profiling techniques such as the refracted near-field (RNF) or transverse interferometry (TI) measurements, and by measurement of the near field of a fully illuminated core such as the transmitted near-field measurement (TNF).

It is recommended that curve fitting be used with both the index profiling and the TNF techniques to improve the measurement precision of the core diameter.

NOTE 1 Typically, k = 0,025 for either the fitted profiling methods or the unfitted TNF method, and is equivalent to k = 0 for the fitted TNF method.

NOTE 2 For fibres with refractive index profiles that have gradual transition region at their core/cladding boundary, a value of k = 0,05 for the unfitted TNF method is equivalent to k = 0 for the fitted TNF method.

NOTE 3 For category B fibres, the centre of the core is defined as the centre of the near field profile and not of the refractive index profile. The core boundary is not defined. Instead, the mode field diameter is defined and specified.

5 Reference test method

The reference test method (RTM), which shall be the one used to settle disputes, depends on fibre category such as:

- category A fibres: method C

  NOTE The characteristics of the core of category A fibres are defined in terms of refractive index profile, which is measured with method A. Use method C to settle disputes with regard to cladding diameter, cladding non-circularity and core-cladding concentricity error of category A fibres.

- category B fibres: method C.

6 Apparatus

Annexes A, B, C and D include layout drawings and other equipment requirements for each of the methods A, B, C and D, respectively.

7 Sampling and specimens

7.1 Specimen length

See annexes A, B, C and D, respectively, for the applicable requirements.

7.2 Specimen end face

For methods A and C only, prepare a clean, flat end face, perpendicular to the fibre axis, at the input and output ends of each specimen. The accuracy of measurements performed by methods A and C is affected by a non-perpendicular end face. End angles less than 1° are recommended.

See C.2 for the tighter requirements on end faces when using method C.

Because method D is side-view only, it does not have tight end face requirements.

8 Procedure

Use the procedures given in IEC 61745 for calibration. Annexes A, B, C and D document the procedures for methods A, B, C and D, respectively.

9 Calculations

See annexes A, B, C and D for methods A, B, C and D, respectively.

10 Results

The following information shall be provided with each measurement:

- date and title of measurement;
- identification and description of specimen;
- measurement results for each parameter specified (see applicable annex).

The following information shall be available upon request:

- measurement method used: A, B, C, or D;
- specimen length;
- arrangement of measurement set-up;
- details of measurement apparatus (see applicable annex);
- relative humidity and ambient temperature at the time of the measurement;
- most recent calibration information.

11 Specification information

The detail specification shall specify the following information:

- type of fibre to be measured;
- failure or acceptance criteria;
- information to be reported;
- any deviations to the procedure that apply.

Annex A
(normative)

Requirements specific to method A – Refracted near-field

The refracted near-field measurement directly measures the refractive index variation across the fibre (core and cladding). The method can be calibrated to give absolute values of refractive indexes. It can be used to obtain profiles of both single-mode and multimode fibres

A.1 Apparatus

See figures A.1 and A.2 for schematic diagrams of the test apparatus.

A.1.1 Source

Provide a stable laser giving a few milliwatts of power in the TEM_{00}.

A HeNe laser, which has a wavelength of 633 nm, may be used, but apply a correction factor to the results for extrapolation at different wavelengths.

Introduce a quarter-wave plate to change the beam from linear to circular polarization because the reflectivity of light at an air-glass interface is strongly angle and polarization-dependent.

If necessary, place a spatial filter, such as a pin-hole, at the focus of lens 1.

A.1.2 Launch optics

Arrange the launch optics to overfill the numerical aperture (NA) of the fibre. This brings a beam of light to a focus on the flat end of the fibre. The optical axis of the beam of light should be within 1° of the axis of the fibre. Determine the resolution of the equipment by the size of the focused spot, which should be as small as possible in order to maximize the resolution, e.g. less than 1,5 μm. The equipment enables the focused spot to be scanned across the fibre diameter.

A.1.3 Liquid cell

The liquid in the liquid cell shall have a refractive index slightly higher than that of the fibre cladding.

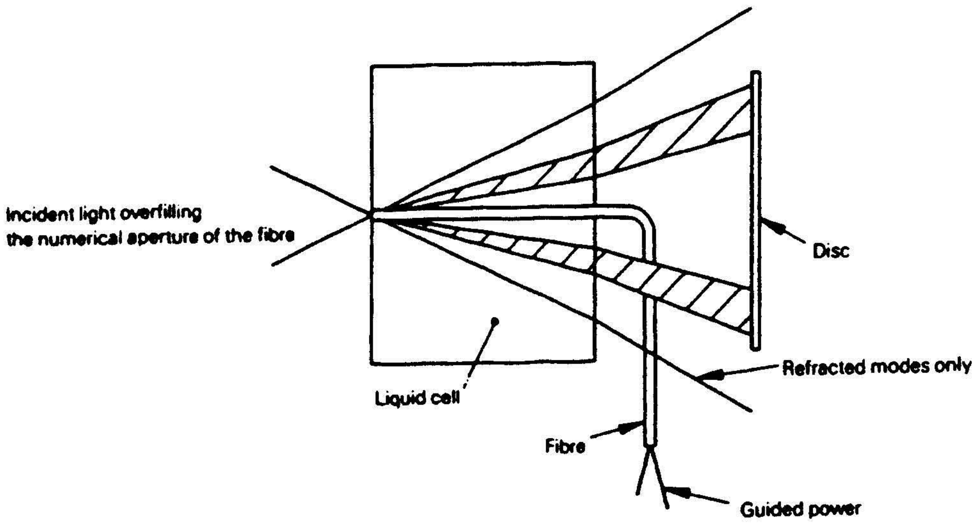

Figure A.1 – Refracted near-field method — Schematic diagram

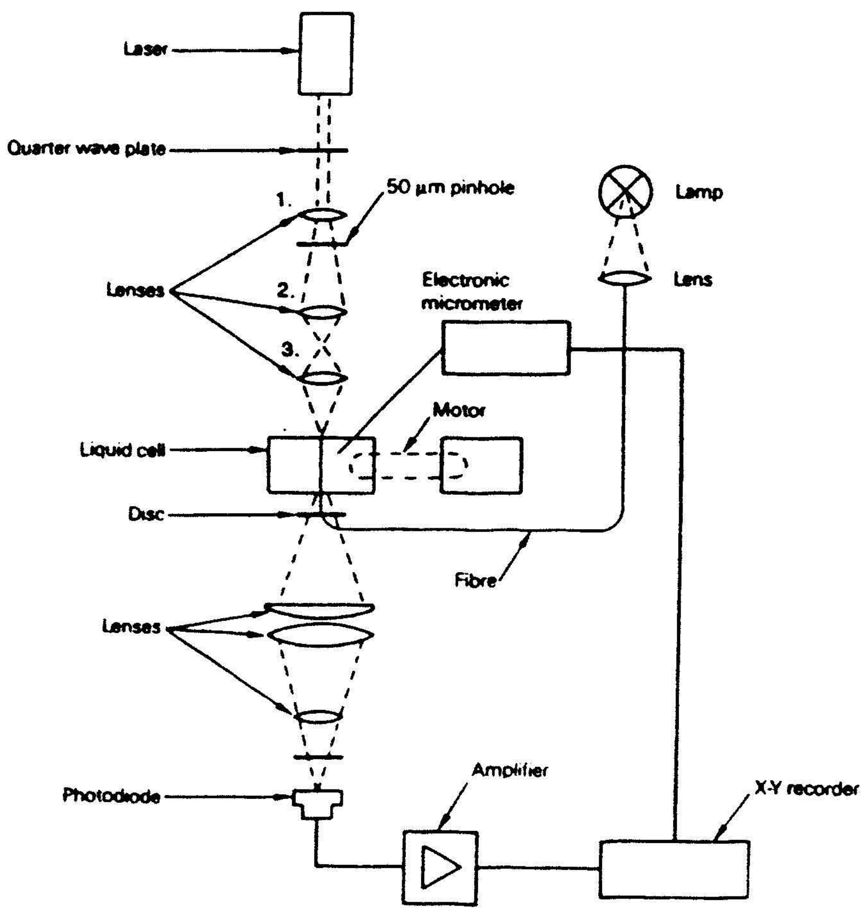

Figure A.2 – Typical arrangement of the refracted near-field test set

A.1.4 Sensing

Provide a suitable way to collect the refracted light and bring it to the detector, making sure that all the refracted light is captured. By calculation, determine the required size of the disc and its position along the central axis.

NOTE Typically the blocking disc is chosen so that it subtends a numerical aperture (NA) approximately equal to the NA of the launch optics divided by $\sqrt{2}$

A.2 Sampling and specimens

Use a length of fibre less than 2 m.

Remove all fibre coatings from the section of fibre to be immersed in the liquid cell.

A.3 Procedure

Figure A.2 is a schematic diagram of the test apparatus.

A.3.1 Fibre index profile plot

Immerse the launch end of the fibre to be measured in a liquid cell whose refractive index is slightly higher than that of the fibre cladding. The location of the fibre can be determined by a method such as back illumination with a tungsten light. Lenses 2 and 3 produce a focused image of the fibre.

Adjust the position of lens 3 to centre and focus the fibre image, and simultaneously centre and focus the laser beam on the fibre.

Centre the disc on the output cone. For category A multimode fibre, position the disc on the optical axis to just block the leaky modes. For category B single-mode fibre, position the disc to give optimum resolution.

Collect the refracted modes passing the disc and focus them onto a photodiode. Traverse the focused laser spot across the fibre end, and directly obtain a plot of the fibre refractive index variation.

A.3.2 Equipment calibration

During the measurement, the angle of the cone of light varies according to the refractive index seen at the entry point to the fibre (hence the change of power passing the disc). With the fibre removed and the liquid index and cell thickness known, this change in angle can be simulated by translating the disc along the optic axis. By moving the disc to a number of predetermined positions, the profile can be scaled in terms of relative index. Absolute indices, i.e. n_1 and n_2, can only be found if the cladding index or the liquid index, at the measurement wavelength and temperature, is known accurately.

A multi-level calibration artifact, such as available from national standards institutes, may also be used to complete calibration, according to the instructions provided.

A.4 Calculations

From the raster scan of the cross-section of the profile, calculate any or all of the following quantities:

- core diameter;
- cladding diameter;
- core/cladding concentricity error;
- core non-circularity;
- cladding non-circularity;
- maximum theoretical numerical aperture;
- index difference;
- relative index difference;
- indications of accuracy and reproducibility.

Different techniques for determining the cladding boundary can be used; one example is the decision-level technique. It is essential to use the same decision level for the cladding boundary as the one used in the calibration procedure.

A.5 Results

In addition to the results listed in clause 10, and depending on the specification requirements, the following information shall be provided on request:

A.5.1 Profiles through core and cladding centres calibrated for a given wavelength.

A.5.2 Profiles along the core major and minor axes calibrated for a given wavelength.

A.5.3 Profiles along the cladding major and minor axes calibrated for a given wavelength.

A.5.4 Equipment arrangement and wavelength correction procedure.

Annex B
(normative)

Requirements specific to method B – Transverse interference

This test method establishes procedures to be followed for determining the refractive index profile, $n(r)$, of an optical fibre specimen by transverse interferometry. The glass geometry characteristic parameters are then obtained by calculations involving the measured refractive index profile.

The method is based on the use of an interference microscope focused on the side view of a fibre specimen that is illuminated perpendicular to its axis so as to generate a fringe pattern. The refractive index profile is obtained from video detection and digitization of the interference fringes under computer control.

This method is particularly suited for the measurement of a core diameter and a maximum theoretical numerical aperture of a category A fibre, but is less well suited for parameters related to the cladding.

B.1 Apparatus

Figure B.1 shows the equipment necessary to make this measurement.

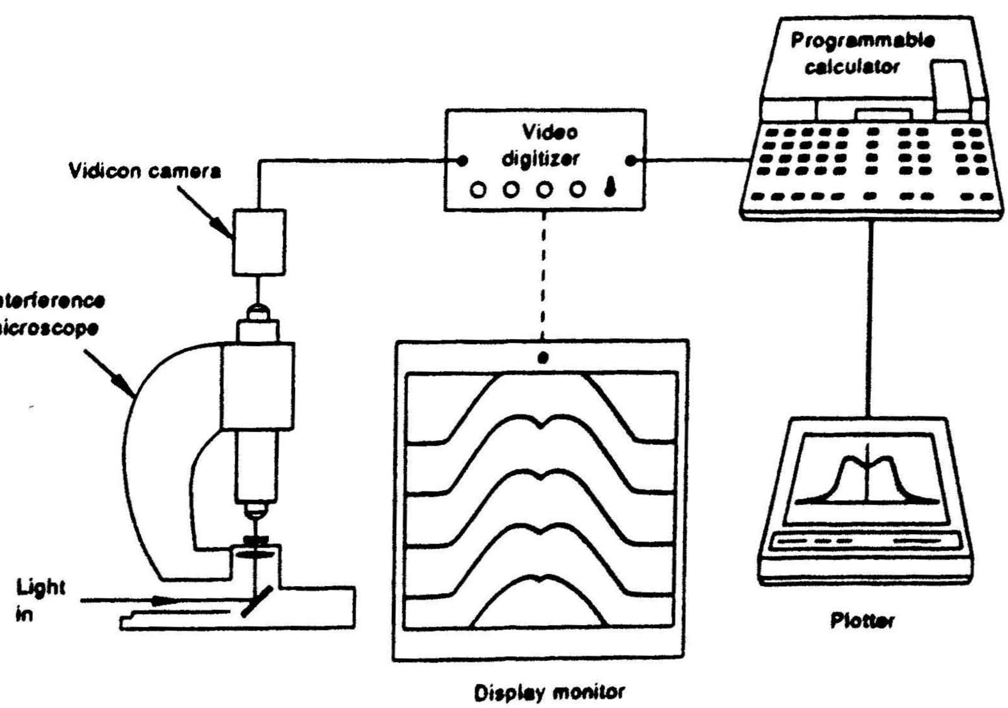

Figure B.1 – Test apparatus

B.1.1 Transmitted light-interference microscope

This special-purpose microscope is a combination of two microscopes and an interferometer allowing the magnified image of the test objects to appear together with the interference fringes. A parallel condenser and objective lens system create a sample test path and a reference path for the quasi-coherent illuminating light obtained using a narrow-band filter and a white light source.

B.1.2 Television camera and monitor

The camera produces an electronic picture that permits the quantification of fringe shading so that analytical methods can be utilized to locate precisely the centre coordinates of a fringe. It also permits measurements to be made at wavelengths outside the visible spectrum. The monitor allows the operator to view the test specimen easily and aids in the set-up procedures necessary to provide proper adjustment of the specimen and the fringes.

B.1.3 Video digitizer

This unit operates with the camera and computer controller so that the output field of the microscope as seen by the camera can be digitized. The computer addresses a location on the camera vidicon, and the digitizer returns to the calculator, for example, an 8-bit binary number indicating shade of grey at the addressed location. The location of the point being encoded is indicated by a dot cursor on the monitor as an operator aid.

B.1.4 Computer and plotter

The computer accumulates intensity versus position data so that the displacement of a fringe from its cladding level can be determined as a function of core radial position. The computer calculates Δn and then plots the index profile along with the radial coordinates. The computer then determines a best-fit power-law curve to the index profile, and the curve is drawn by the plotter.

B.2 Sampling and specimens

Use a 20 mm length of clean, uncoated fibre for the specimen.

B.3 Procedure

B.3.1 Preparation

Place the specimen on its side under the test objective of the microscope on an optically flat specimen plate (supplied with the microscope). Then place equal amounts of oil having a refractive index equal to that of the cladding on the specimen plate and on the reference plate. Using $\times 100$ immersion objectives, raise the stage of the microscope until the objectives are in contact with the oil. Then locate the fibre in the field of view of the objective and focus it with the reference beam blocked. Then unlock the reference beam and adjust the microscope controls to produce a high-contrast fringe pattern, as illustrated on the display monitor in figure B.1, where the curves in the fringes are caused by the core.

B.3.2 Axis orientation

Orient the fibre axis perpendicular to the fringe lines and adjust the separation between fringe lines using microscope controls so that approximately four fringes are visible on the monitor. For convenience of analysis, make the fringe lines parallel to the horizontal scan lines of the camera, again using microscope controls.

B.3.3 Scanning

Once the fringes are properly oriented, the programmable calculator and digitizer automatically scan a selected fringe to obtain the amount of shift (Y axis) in the core, using the position of the fringe in the cladding as the zero shift (Y = 0) position. Make a separate scan vertically across two adjacent fringes in the cladding to obtain the fringe separation, L. Once the fringes have been scanned, determine a set of fringe-shift points, Q_p, and fringe separation, L, for use in calculating n_p. Here p is the number of radial positions at which the fringe shift is measured.

B.4 Calculations

For the purpose of analysis, approximate the refractive index profile of the fibre core by a series of concentric rings (see figure B.2). The top portion of figure B.2 shows the fringe and the correlation of fringe shift points to unbent paths traversing the core. These fringes need not coincide with the deposition layers in the fibre, depending on how much spatial resolution is desired in $n(r)$. Assume that the refractive index within a ring is constant in this approximation. The index of the ring, p, exceeds that of the cladding by:

$$\Delta n_p = \frac{1}{S_{p,j}} \left[\frac{\lambda Q_p}{L} - \sum_{j=1}^{p-1} Dn_j S_{p,j} \right] \tag{B.1}$$

where $S_{p,j}$ is the distance the p ray travels in the j ring:

$$S_{p,j} = 2\left\{ \left[R_{j-1}^2 - R_p^2\right]^{1/2} - \left[R_j^2 - R_p^2\right]^{1/2} \right\} \tag{B.2}$$

Here R_j is the radius of ring j, Q_p is the fringe shift at p, and L is the spacing of adjacent fringes.

Once the calculated Δn_p is complete, plot these data on the X-Y plotter. This is the index profile of the fibre. Use additional calculations using curve fitting techniques to obtain parameters that best match the model refractive index equation:

$$\Delta n(r) = \Delta n_0 \left[1 - (r / a)^g\right] \tag{B.3}$$

where

Δn_0 is the refractive index difference at r = 0;

a is the core radius;

g is the shape factor, approximately 2.

The fitting procedure determines the Δn_0, g, and a values that result in the best fit to the actual profile. In the fitting procedure, use only data between 0,15 a and 0,95 a so as to avoid unacceptable disturbances caused by the centre index dip and the core/cladding boundary irregularities. A nominal value of a may be used to determine the limits of the curve fit.

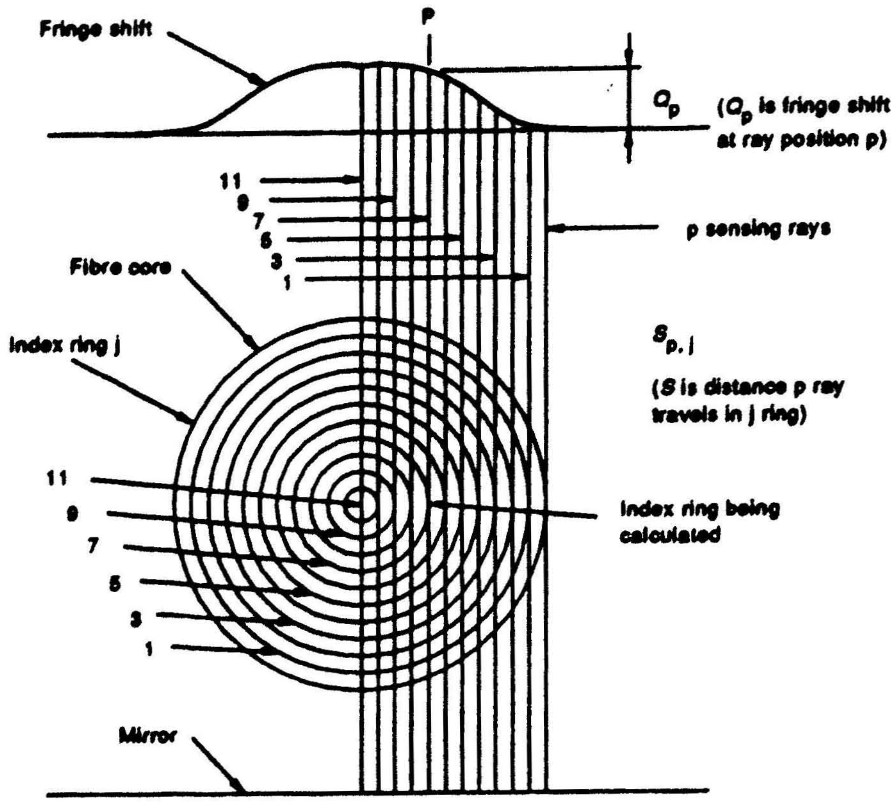

Figure B.2 – Refractive index profile – Ring pattern

B.5 Results

In addition to the results listed in clause 10, and depending on the specification requirements, the following information shall be provided on request.

B.5.1 Central wavelength and spectral width (FWHM) of illuminating light.

B.5.2 Type of interferometer used.

Annex C
(normative)

Requirements specific to method C – Near-field light distribution

This test method determines the geometry parameters of category A and category B fibres by analyzing the near-field light distribution on a cross-section at the end of the fibre under test. There are two techniques: grey-scale technique, which performs a two-dimensional, *X-Y*, near-field scan using a video system; and the single near-field scan technique, which performs a one-dimensional scan. The manufacturer and the customer should agree upon the particular technique.

C.1 Apparatus

C.1.1 Light sources

Use suitable incoherent light sources for the illumination of the core and the cladding, adjustable in intensity and stable in intensity over a time period sufficient to perform the measurement.

C.1.2 Light-source wavelength

For the core and cladding illumination, the centre wavelength and the spectral width shall be as specified.

NOTE The core diameter of category A fibres has not been found to be dependent on the wavelength of the source. Even white-light illumination can be used.

For the cladding illumination, the spectral width shall be less than or equal to 100 nm. The wavelength of the cladding shall not cause defocusing of the core image.

C.1.3 Launching conditions

Arrange the launch optics such that the light source uniformly overfills the specimen angularly and spatially. At the output end uniformly illuminate the cladding as well.

C.1.4 Fibre support and positioning apparatus

Provide a sufficiently stable means of supporting the specimen input and output ends, for example, a vacuum chuck. Mount this support on a positioning device so the fibre end can be accurately positioned in the input beam and output path.

C.1.5 Cladding mode stripper

Unless otherwise specified, use devices that strip cladding mode light from the specimen reasonably near the fibre input and output ends. When the fibre under test has a primary coating with a refractive index higher than that of the glass, this coating acts as the cladding mode stripper.

C.1.6 Magnifying optics

Provide suitable optics that magnifies the output near-field image of the specimen so that this magnified image can be suitably scanned. The numerical aperture, and hence the resolving power of this lens, shall be compatible with the measuring accuracy, and not lower than 0,3.

When using the grey-scale technique, select the magnification so that the charged-coupled device (CCD) array of the video camera is nearly filled by the cladding image.

Calibrate the optical system in conjunction with the scanning system so that the dimensions in the plane of the fibre output end face are known. (It is not necessary to know the optical system magnification exactly.)

C.1.7 Detection

For the grey-scale technique, use a CCD video camera to detect the magnified output near-field image and transmit it to a video monitor. The video digitizer performs the digitization of the image for further computer analysis. This video system shall be sufficiently linear so that, after calibration, the measurement uncertainty is not greater than required.

For the single near-field scan technique, provide a means of scanning the focused image of the fibre near-field pattern, which provides knowledge of the distance scanned. An example is a single detector (such as a pin-hole) placed on a stepper-motor-driven translator with a position feedback device, or a video-array detector of known element size and spacing. The detector shall be linear over the range of intensities encountered.

The pixel size of the camera, or the size of the detector (or pin-hole), shall be sufficiently small compared with the magnified near-field image as to be less than the system diffraction limits by a factor of 2. That is:

$$d \le \frac{1{,}22 M\lambda}{4\mathrm{NA}} \qquad \text{(C.1)}$$

where

- d is the pixel size of the camera, or the detector (pin-hole) size in µm;
- M is the approximate magnification of the optical system;
- λ is the (lowest) test wavelength;
- NA is the numerical aperture of the specimen for core diameter measurements of category A fibres, or the numerical aperture of the objective in the case of cladding diameter measurements.

C.1.8 Video image monitor (grey-scale technique)

Use a video image monitor to display the detected image. The screen on the monitor typically shows a pattern, such as cross-hairs, to assist the operator in centering the image of the specimen. Computer-controlled alignment and/or focusing may be used.

C.1.9 Data system

For the grey-scale technique, perform the measurements, data acquisitions and calculations using a computer. A printer provides a hard copy of the information and measurement results

For the single near-field scan technique, provide appropriate means to record the near-field intensity as a function of scan position. This could be an X-Y chart recorder, a digital processor or other suitable device.

C.2 Sampling and specimens

Prepare the specimen to have fibre ends that are clean, smooth and perpendicular to the fibre axis. Typically, an end angle <1° from normal to the fibre axis is necessary for the cladding measurement. Control the end damage for minimum impact on the measurement accuracy and/or precision. The length shall be 2 m ± 0.2 m for fibre categories A1, A2, A3 and A4. There is no length restriction for category B fibre. Take care to avoid sharp bends on the fibres.

C.3 Procedure

C.3.1 Equipment calibration

Specimens of known diameter, provided by a national standards laboratory, shall be used to calibrate the apparatus according to the procedures given in IEC 61745.

C.3.2 Measurement

C.3.2.1 Measurement by the grey-scale technique

Using fibre holders, align the specimen at the input end to achieve the launch condition specified. Focus the near-field image of the output end, and center it in the monitor. Adjust the intensity of the core illumination at the input end and the intensity of the cladding illumination at the output end according to an established, internal standard for the particular test equipment.

Record the digitized video data from the image of the output end face. Several data sets may be averaged.

C.3.2.2 Measurement by the single near-field scan technique

Prepare, secure and align the specimen as indicated above. Adjust the output end to permit the magnified image to be scanned. Scan the near-field image, and record the intensity as a function of position in the plane of the fibre output end.

C.3.3 Decision levels

The decision levels of the different boundaries of core and cladding in the near-field image are as follows.

C.3.3.1 Core boundary

For category A fibres this level is according to the definition of 4.3.

For category B fibres this level is according to the definition of 4.2.

C.3.3.2 Cladding boundary

Different techniques for determining the cladding boundary can be used, one example being the decision-level technique. It is essential to use the same decision level for the cladding boundary as the one used in the calibration procedure.

C.4 Calculations

C.4.1 Calculations for the grey-scale technique

The raw data of the core and cladding boundary are fitted to smooth mathematically closed forms, such as an ellipse, in order to determine the best estimates of the actual edges. The smooth, mathematically closed forms are then fitted to a circle in order to determine the first-order deviations from the ideal circular shape. These values and the mathematical edge representations are used to determine the parameters of clause 3, as follows:

R_{co} (µm):	fitted core radius
X_{co}, Y_{co} (µm):	fitted core centre
$R_{min\ co}$ (µm):	minimum distance, core edge to centre
$R_{max\ co}$ (µm):	maximum distance, core edge to centre
Core diameter (µm):	$2\ R_{co}$
Core non-circularity (%):	$100\ (R_{max\ co} - R_{min\ co})\ /\ R_{co}$
R_{cl} (µm):	fitted cladding radius
X_{cl}, Y_{cl} (µm):	fitted cladding centre
$R_{min\ cl}$ (µm):	minimum distance, cladding edge to centre
$R_{max\ cl}$ (µm):	maximum distance, cladding edge to centre
Cladding diameter (µm):	$2\ R_{cl}$
Cladding non-circularity (%):	$100\ (R_{max\ cl} - R_{min\ cl})\ /\ R_{cl}$
Core/cladding concentricity error (µm):	$\left[(X_{cl} - X_{co})^2 + (Y_{cl} - Y_{co})^2\right]^{½}$

The smooth, mathematically closed forms used to represent the edges are required in order to allow a variation of curvature that is greater than or equal to that found in an ellipse. For non-elliptical forms, the data can be converted to polar coordinates about a roughly estimated centre before fitting the radius vs. angular position.

Active filtering, or removal of raw data points that represent cleave damage from those that are fitted to the mathematical form, is allowed. The choice of the curve, the test equipment, the cleave method and the filtration algorithm are interactive in their contribution to the quality of the cladding measurement results.

The following forms are examples of fitting functions that may be used, depending upon equipment availability.

C.4.1.1 Ellipse

Fit the x, y pairs to the ellipse by using the "least sum of squares (LSS)" technique. An iterative process of active filtering may be used.

C.4.1.2 Fourier transform

Filter the transform by setting the coefficients above some period, the truncation period, to zero. The maximum truncation period is 180°, corresponding to an ellipse. Typically, the truncation period is 90°. (For 64 data points, this corresponds to the fourth Fourier term above the zero-frequency reference.)

C.4.1.3 Circular cubic spline

In polar coordinates, the abscissa is divided into a number of equal intervals. Each interval is represented by a distinct cubic equation. The equations are required to be equal in value, first derivative and second derivative at the interval boundaries, including the 0°, 360° boundary. The number of intervals shall be at least five, corresponding to an ellipse. As many as twelve intervals are used.

C.4.2 Calculations for the single near-field scan technique

Normalize the output near-field pattern to the peak detected intensity and plot as a function of the effective scan position in the plane of the fibre output end. Two options are available to calculate the core diameter.

NOTE The cross-sectional diameter may deviate from the core diameter determined by the grey-scale technique due to core non-circularity.

C.4.2.1 Option 1 – No curve fit

Determine the cross-sectional diameter directly from the measured pattern at the k level defined in 4.3. See figure C.1.

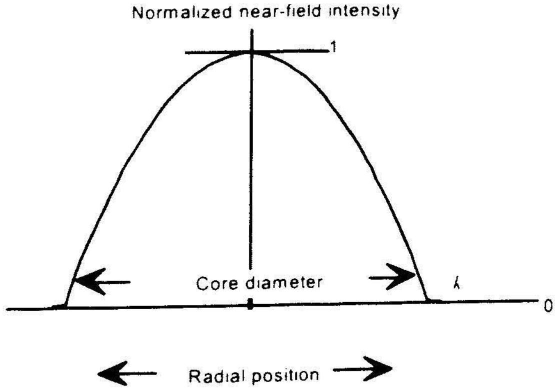

Figure C.1 – Cross-sectional core diameter – Near-field intensity scan, option 1

C.4.2.2 Option 2 – Curve fit

The least squares method fits the portion of the normalized radiation pattern, $I(r)/I(0)$, between the 10 % and 80 % points to the following power-law expression:

$$I(r)/I(0) = 1 - (r/a)^g \tag{C.2}$$

where a is the core radius and g is the power-law exponent. Variables in the fit include a, $I(0)$, and g. Choose the curve-fitting algorithm so that the results do not significantly depend upon details of the algorithm.

Obtain the cross-sectional diameter from the fitted power-law curve at $I(a) = 0$, i.e. the diameter is equal to $2a$, where a is the radius. See figure C.2.

NOTE Studies have shown that options 1 and 2 give approximately the same value for the cross-sectional core diameter. See figure C.3.

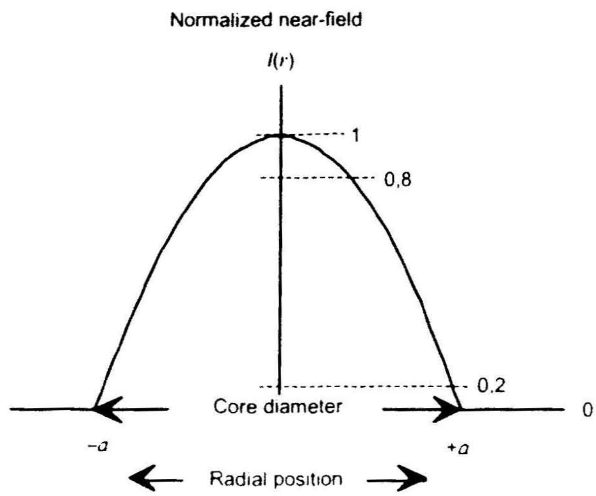

Figure C.2 – Cross-sectional core diameter – Near-field intensity scan, option 2

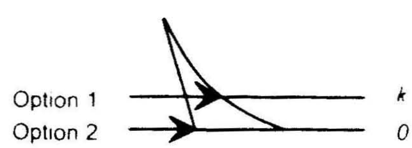

Figure C.3 – Near-field intensity distribution in the region of the core-cladding boundary

C.5 Results

In addition to the results listed in clause 10, and depending on the specification requirements, the following information shall be provided on request.

C.5.1 Detector type and aperture size (single near-field scan technique only).

C.5.2 Details of single near-field scan technique and estimated resolution (single near-field scan technique only).

Annex D
(normative)

Requirements specific to method D – Mechanical diameter

This is a mechanical diameter measurement technique for accurately determining the cladding diameter of silica fibres (types A1 and A2, and all category B). Use this technique to provide calibrated fibre specimens to the industry as standard reference materials.

D.1 Apparatus

The measurement uses two anvils in order to make contact with each side of the fibre under test. The faces of the anvils shall be flat and parallel and the applied force shall be small enough to ensure that the anvils do not physically distort the fibre. Alternatively, if either or both of the anvils are not flat, and if the fibre is distorted by the anvils, then a correction shall be made for compression.

Refer to the schematic diagram of the apparatus (figure D.1)

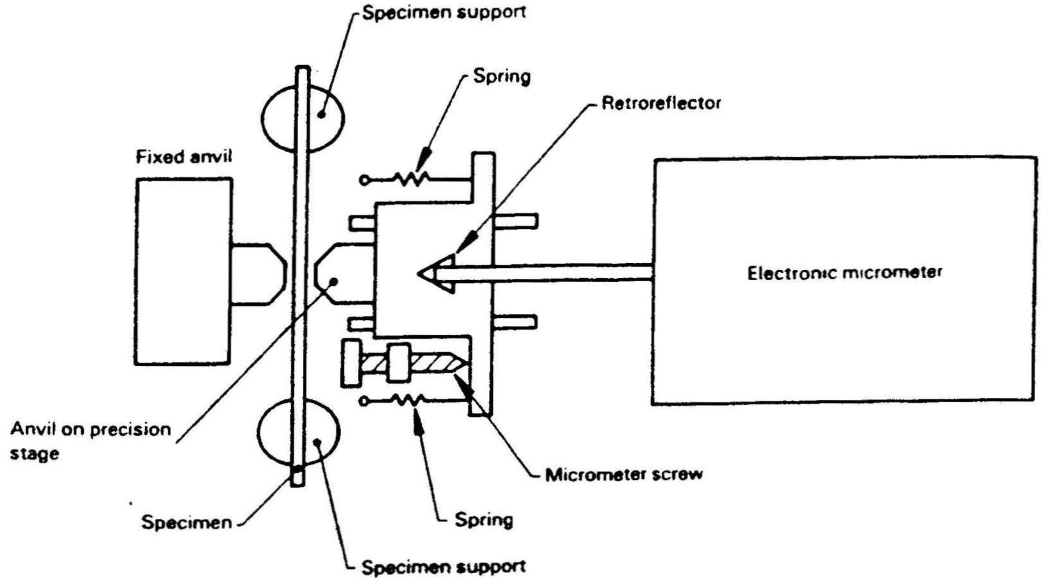

Figure D.1 – Top view of a typical electronic micrometer system

D.1.1 Anvils

There are two anvils, one fixed and the other movable. The movable anvil shall be mounted on a micromanipulator, or it may move freely, as on an air bearing. The movable anvil shall be held against the fixed anvil or the fibre by springs, or by a force developed by a hanging weight, or by any other reproducible means

D.1.2 Electronic micrometer system

An electronic micrometer system, such as a double-pass Michelson interferometer, may be used with a retroreflector or a plane mirror to measure accurately the movement of the stage, and thus the movable anvil.

D.1.3 Specimen support

Support the specimen between the faces of the anvils. Short specimens may protrude from a ferrule, or a V-block, or other similar fixture.

D.2 Sampling and specimens

The specimen may be any length, or as specified in the detail specification.

When making cladding diameter measurements, remove all coating or buffer, or both, completely.

Because the end faces of the specimen are not involved in the measurement itself, it is not necessary to have tight end-face requirements.

D.3 Procedure

D.3.1 Principle of the measurement

The diameter of the specimen is measured by contacting opposite sides with the anvils [1] [1]. The contact force may be adjusted so that there is negligible distortion of the specimen and the anvils. The actual force used shall be agreed upon by the supplier and the user, and may depend on the materials of the specimen or the anvils.

The separation of the anvils is accurately measured with the electronic micrometer.

If distortion is not negligible, make a mathematical correction of the measured separation.

D.3.2 Measurement

Clean the anvil faces and turn the micrometer screw in order to bring the anvil faces into contact with each other. Further turn the micrometer screw so that the anvils are held together by the spring tension only. Record the electronic micrometer distance reading.

Next, adjust the micrometer so that the gap between the anvil faces is larger than the specimen diameter. Place the specimen fibre on the supports between the anvil faces. Turn the micrometer screw slowly in order to bring the anvil faces into contact with the fibre so that the anvils are held against the fibre by the spring tension only. Record the electronic micrometer distance reading. The difference between the first and second readings, plus any corrections due to compression, is the specimen diameter. Repeat the measurement a few times to ensure repeatability.

---

[1] Figures in square brackets refer to the bibliography.

D.4 Calculations

Record the specimen average diameter and standard deviation derived from a number of measurements in order to indicate measurement repeatability.

Determine non-circularity of fibre by a series of measurements in which the fibre is rotated between each measurement.

D.5 Results

In addition to the results listed in clause 10, and depending on the specification requirements, the following information shall be provided on request.

D.5.1 A description of the apparatus, including the anvil materials and the contact force.

D.5.2 The correction factor, if used.

GMGIPN—265 BIS/ND/2009—300 Copies

Bureau of Indian Standards

BIS is a statutory institution established under the *Bureau of Indian Standards Act*, 1986 to promote harmonious development of the activities of standardization, marking and quality certification of goods and attending to connected matters in the country.

Copyright

Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard alongwith amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Catalogue' and 'Standards: Monthly Additions'.

This Indian Standard has been developed from Doc No.: LITD 11 (2009).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

BUREAU OF INDIAN STANDARDS

Headquarters :

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002
Telephones: 2323 0131, 2323 3375, 2323 9402 *Website*: www.bis.org.in

Regional Offices :

			Telephones
Central	:	Manak Bhavan, 9 Bahadur Shah Zafar Marg NEW DELHI 110002	2323 7617 2323 3841
Eastern	:	1/14 C.I.T. Scheme VII M, V.I.P. Road, Kankurgachi KOLKATA 700054	2337 8499, 2337 8561 2337 8626, 2337 9120
Northern	:	SCO 335-336, Sector 34-A, CHANDIGARH 160022	260 3843 260 9285
Southern	:	C.I.T. Campus, IV Cross Road, CHENNAI 600113	2254 1216, 2254 1442 2254 2519, 2254 2315
Western	:	Manakalaya, E9 MIDC, Marol, Andheri (East) MUMBAI 400093	2832 9295, 2832 7858 2832 7891, 2832 7892

Branches : AHMEDABAD. BANGALORE. BHOPAL. BHUBANESHWAR. COIMBATORE. DEHRADUN. FARIDABAD. GHAZIABAD. GUWAHATI. HYDERABAD. JAIPUR. KANPUR. LUCKNOW. NAGPUR. PARWANOO. PATNA. PUNE. RAJKOT. THIRUVANANTHAPURAM. VISAKHAPATNAM.

PRINTED BY THE GENERAL MANAGER, GOVT. OF INDIA PRESS, NASHIK-422 006

265 BIS/ND/2009